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Jacques Monod

From Biology To Ethics

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From Biology To Ethics

The Salk Institute for Biological Studies

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No less does fittingness tell in the shape and bulk of diverse fruits. Many are sized unto the mouth of man, like the cherry and the plum; others unto his hand, like the pear and the apple; still others, much larger, such as the melon, are divided into sections and seem meant for family fare. There are even some, like the jack-fruit of the Indies or our own pumpkin, which could be shared among neighbors.

—Bernardin de Saint-Pierre

Mr. Director,
Dear Colleagues,
Ladies, Gentlemen,

The Chair which at its assembly last year the Collège de France proposed to dedicate to Molecular Biology, was founded for the Abbé Rousselot in 1923, who then held it as a Chair of Experimental Phonetics. Subsequently, with M. Jolly, it became the Chair of Histophysiology; with M. Lacassagne, that of Experimental Radiobiology; and resumed its name of Histophysiology during the tenure of M. Jacques Benoit.

The declared ambition of my discipline, or rather its ideal, would be to provide Biology with the complete conceptual unity it yet lacks. Through your decision to devote this Chair to Molecular Biology, you declare your concern, my dear colleagues, that my predecessors' major effort be carried on. When one grasps the full importance and the profound originality of M. Lacassagne's discoveries in the growth-process of cancer, when one takes stock of the extent of M. Jacques Benoit's work in endocrinology, a formidable task it must appear, this that you have entrusted to me. You have thought me worthy to undertake it and, while attesting my deepest gratitude, I cannot hide from myself, or from you, that others long before me have possessed a better claim to this so very high honor. I am thinking particularly of André Lwoff, whose

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example I have done no more than try to follow, and from whom I have learned that the sharpest criticism can also be generous, and that severest scientific exactitude, rather than forbidding, actually authorizes and encourages enthusiasm for the boldest speculations.

My pride is great, my joy is profound to find myself today, thanks to yourselves, Gentlemen, a member of this illustrious College: an exemplary institution, unique in that it is devoted to knowledge sought after, cultivated, elaborated for its own sake, pursued without deference to any contigency, in the interests of enlightenment alone.

Formulated more than four centuries ago, in one of the most fertile periods in the history of human thought, this admirable program has been conducted by you, Gentlemen, and by your predecessors, unflaggingly and without concession. Never was this program more justified and more necessary than at present: for through a strange reversal, the prodigious development of science, the immense technical, political, social, intellectual upheavals it has provoked today entail new dangers for science.

Science has bestowed immense powers upon men. But over and above atrocious abuses in their employment, the very source of science, in objective knowledge and in the ethic which grounds it, remains obscure for the majority of mankind. Whence this anxiety, this deep-lying mistrust that most of our contemporaries possess before the modern world and science itself. A feeling of alienation which is far from being confined to the least cultivated: some of the most compelling tendencies in contemporary literature and philosophy derive directly from this alienation, sometimes expressly proclaimed.

There are few clearer or more urgent duties today facing the community of men of science than of combatting this modern schizophrenia. And how is it to be fought if not by the deepening of knowledge itself, by constantly extending the objective method into new domains, in fine, by an education dispensed without hindrance and without sanction to free men?

Such was from the outset and such still is the program of the Collège de France, as exemplary as ever in the past. But I may perhaps be allowed to dwell upon a point that is close to my heart. I believe that as the scope of science broadens further and with increasing speed, confrontations between disciplines become more than ever necessary. The absence of any dividing walls within the Collège de France, the absence of any administrative barriers between the various disciplines represented here, is therefore, to my mind, a blessing. I, for my part, have already had the opportunity to appreciate its value, manifested to me during the personal meetings a number of you had the kindness to grant me, and in whose course I presumed, frequently, to question you concerning your disciplines, when by the predications of custom it befitted me only to reply to questions about mine. Of such great interest to me were those encounters that, let me confess it, I sometimes regret I am no longer a candidate but already passed the year's end examination and "diplomaed." For I must fear, is it not so, that I shall henceforth find fewer occasions for these precious exchanges. Confrontations, comparisons which are nevertheless so very necessary; for in the universe of knowledge the expansion is such that from its farthermost galaxies, the isolated observer may shortly cease to receive any light.

To avoid such isolation, to contribute not only to knowledge but also to maintaining its unity, this too is a permanent duty of the scientific community. No institution is better appointed to this office, none apter to fulfill this function than the Collège de France. A deliberate policy could probably go still farther in fostering this communication between disciplines. But that it be fruitful, it must remain spontaneous and free, in keeping with the very spirit of the College.

For a being to be ontological in no wise signifies that it has already elaborated an ontology.

—Martin Heidegger

If I am particularly alive to these problems, that may be because my discipline, through its subject, lies exactly on the frontier between the physical and living worlds. Wholly based on the given data and methods of the physical sciences, it seeks to interpret, in terms of molecular structures and interactions, those biological phenomena which are most exclusively characteristic of the living world.

Need it be recalled that vis-à-vis the physical laws that govern the evolution of macroscopic systems, the very existence of living beings assumes the look of a challenge? Of all the known objects or systems in the universe, only living beings possess two paradoxical properties, which I shall here call, as others have done, Emergence and Teleonomy.

Emergence is the property of reproducing and multiplying highly complex, ordered structures; it likewise allows the evolutionary creation of increasingly complex structures.

Teleonomy is the expression to use if, at the bidding of objectivity, one would rather avoid the words "goal" or "end". Nonetheless, "it is as if" living beings were structured, organized and conditioned in view of a goal: the survival of the individual and particularly of the species.

Clearly these two paradoxical properties, by which living systems seem to stand in radical distinction from non-living systems, are not independent but, on the contrary, closely associated: the teleonomic "project" or "goal" is the multiplication of the species, which is itself one of the properties of emergence.

While it is possible to assign a fairly clear physical meaning to the notion of emergence, for teleonomy it is much more difficult —and for good reason—to propose a definition that is neither circular nor contaminated by subjective elements.

The emergence of a given species can be defined as being proportional to that quantum of information which, passed from one generation to the next, assures the conservation of that species' structural norm. This quantum is in the main measurable.

All the activities, all the operations contributing to the success of this transmission of information are teleonomic phenomena. However, each and every teleonomic operation can be individually considered a transfer of information. And so we may suggest that the average quantum of information which the individual member of any species must, over the course of its life, transfer to its progeny in order to assure the transmission of its own emergence, is an index of its minimum teleonomic "power". Although insufficient, this definition does at least have the virtue of "objectifying biological finalism"; and while distinguishing between the two paradoxical properties, of specifying their intimate interrelationship.

The problem of the causal or temporal relation between emergence and teleonomy underlies all the speculations, all the theories which have been advanced as solutions for these paradoxes. Theories that can be divided into two classes, according to whether they hold that teleonomy insures and directs emergence, or whether, conversely, it is emergence which precedes teleonomy.

Thus, the various "vitalist" theories, more or less scientific in their appearance, all presuppose the existence of a teleonomic principle, of a special guiding force present in living matter, absent in inanimate matter. We need not tarry over these hypotheses; their sterility has been long since established. To illustrate their insignificance, it will suffice to note that the expression "living matter" is itself senseless. There are living systems; there is no living "matter". No substance, no single molecule extracted and isolated from a living being possesses, of its own, the aforementioned paradoxical properties. They are present in living systems only; that is to say, nowhere below the level of the cell. Emergence and teleonomy are properties of the system but not of the substances which constitute it. More recent speculations, owing to a physicist with a rather thin knowledge of biology, propose a more

subtle, but to my mind no less sterile form of vitalism.

The metaphysical solution consists in supposing that emergence and teleonomy are in fact universal properties, simply manifested more intensely in living beings, beginning with—or ending with—man himself. That is Teilhard de Chardin's solution, which, furthermore, is hardly new. In one form or another, whether explicity stated or not, this idea is included in most of the major religious or metaphysical systems. Variously disguised, it is as easily detected in Aristotle's physics as in Teilhard de Chardin's biology, in Hegelian idealism and in dialectical materialism as well.

These are transcendental interpretations, distant cousins of primitive animism. As initial postulate, their "logic" implies a universal teleonomy tending to emergence. This cosmic animism once admitted, there is no further difficulty in explaining the appearance of life and its evolution; to achieve this, it has been enough to deny the Second Law of Thermodynamics:

> *We conclude—and future scientists will have to shed further light on this subject —that the heat radiating in space must necessarily be able to convert itself into some other form of motion; and that in that new form it can immediately be re-concentrated and re-activated. In this way we are free of the one main obstacle to dead suns being re-converted into incandescent nebulae.*
>
> —Engels

Exactly the opposite solution, according to which emergence must *necessarily* precede teleonomy, seems to us today the only rational, the only possible solution, the only one compatible with the Second Law. For while this Second Law is totally irreconcilable with a universal teleonomy of any kind, it in no way excludes the

local emergence of complex structures. However, the genius of a Darwin was required before acceptance could be won for the idea that teleonomy proceeds from the emergence which creates, refines and amplifies it. But Darwin's was yet no more than a logical solution, not a physical interpretation. Darwinian selection accounted for evolution in the biosphere but not for the fundamental properties which make living systems the subjects of this selection. The *ultima ratio* remained still to be found: a physical base for emergence and for the physical nature of elementary teleonomic interactions.

For many years after Darwin, any hope of arriving at such results seemed almost illusory. Today, however, the physical base for this emergence is identified; its structure is established; and this structure accounts for its function. I refer, of course, to DNA, deoxyribonucleic acid: constituent of the chromosome, guardian of heredity, and source of evolution. I shall not retrace here the story of the discovery of this touchstone of biology. With it many names are connected. But I cannot avoid mentioning Avery, who in 1944 gave us direct experimental proof of the hereditary role of DNA; and Watson and Crick, who in 1953 elucidated its structure.

DNA has often been likened to the memory bank of a computer: a legitimate analogy, so long as one thinks only of logical structures but not of functions. A computer's memory contains information or instructions generally expressed within the framework of a binary system. In a strictly comparable manner, the instructions necessary to synthesize the constituents of a cell are contained in DNA in the form of linear sequences involving four chemical radicals; hence in a system of numerical notation based on four rather than two. (Thus the DNA of a higher mammal, such as man, contains a sequence of radicals which allows of twelve billion binary choices; that of an insect, of some two hundred million; and that of a bacterium, of twenty million.)

But the function of DNA inside the cell is radically different from that of the magnetized memory of a computer (at least of those we possess at the present time).

To begin with, the memory bank of a computer generally contains information and a program which bear in no way upon the physical structure of the machine itself; upon, for example, the makeup of its component parts. The information stored in DNA, on the other hand, consists exclusively of prescriptions concerning the synthesis of cellular constituents, that is to say, of the agents which execute the program itself.

Second, a computer's memory is modifiable. It can be fed new instructions, issued from an external source, or enriched by results obtained by the machine itself. The structure (and hence the informational content) of DNA is, to the contrary, essentially invariable, inaccessible to any new "instruction", to any experience undergone by the organism itself.

Finally, and most important, the result—that is to say, objectively, the "aim" of the program inscribed in DNA—is to reproduce exactly, to multiply *ne varietur,* the structure of DNA itself.

In this process of "replication" DNA intervenes directly as the matrix; each of its two strands directs the assembly, in sequence, of the radicals which make up the alphabet of the chemical language, thus printing a new copy of the program, exactly corresponding, letter by letter, to the original. Even though DNA is not, strictly speaking, a crystal, its replication mechanism bears close comparison to crystallization, a phenomenon long cited as an example of emergence in the physical world. This age-old comparison, often derided as naive, comes out fully warranted today: the molecular "base" for emergence in living beings is indeed, as Schrödinger had predicted, an "aperiodic crystal" which is utilized as the model for the unvarying reproduction of its own structure.

This extreme conservatism might seem opposed to variation, and hence to evolution: opposed thereto it indeed is. And this opposition is largely effective; the evolution of the species is undoubtedly less a paradox than its stability. Need we point out that certain species have reproduced themselves without appreciable modification for nearly a billion years?

The contradiction between stability and evolution is only a

seeming one, however. It is apparent at once that through the exact-copy mechanism represented in DNA replication, not only is the preservation of the specific norm obtained, but, with it, the preservation of any fortuitous accident in the reproduction of this norm. For the mechanisms which assure the replication of DNA obviously cannot be absolutely infallible. Let an accident occur, bringing in its wake an error in the reproduction of the program, and that error will be, in its turn, conserved, reproduced, multiplied; unless—which is certainly the case in the vast majority of these accidents—the mistake is such that it brings on the disappearance of the cellular series within which it occurred.

Evolution, the emergence of complex structures from simpler forms, is therefore the consequence of imperfections in the structure-preserving system the cell represents. Far from "guiding" evolutionary emergence, teleonomy contributes to it—blindly, for that matter—only when it goes awry. And one may then say that the same fortuitous events which, by their accumulation, would bring about the disappearance of any structure in non-living systems, in the biosphere conduce to the creation of new and increasingly complex structures.

Everything existing in the Universe
is the creature of chance and of necessity.

—Democritus

Truth to tell, the evolution of the species is not the central problem of biology, not any longer. The frontiers of this discipline, the limits of its *terra incognita* lie nowadays at the two poles of evolution: at the prime sources of emergence and at the most highly refined manifestations of teleonomy. In other words, two problems: that, on the one hand, of the appearance of the very first structures endowed with the capacity for self-reproduction; on the other, that of the functioning of the most highly evolved among teleonomic structures, namely, the central nervous system.

The extreme difficulty of the first of these problems arises from the fact that the "modern" cell, the only one available for our study, is the product of billions of years of merciless selection which has seen it accumulate a formidable teleonomic apparatus wherein it is nearly impossible to discern the vestiges of primitive structures. For if DNA is indeed the molecular base for emergence, it is in itself inert and devoid of teleonomic properties. These properties are revealed only in the activity of the cellular system whose "project" is finally the conservation of the structure of DNA; hence, of the information that structure embodies.

It is important to have some idea of how many and how complex are the operations implied in carrying out such a project. In the "simplest" living system known to us, the bacterial cell, the properly defined metabolism—that is, the sum of the operations which assure the mobilization of the chemical potential of that cell and the synthesis of its essential constituents—calls for more than two thousand reactions, each of them covalent, distinct and stereospecific; and most of these reactions are still beyond the skill of the ablest organic chemist to reproduce. And yet each of these reactions is one hundred percent effective, thanks to the intervention of an enzyme, a specific catalyst acting electively at the level indicated for this one reaction. All enzymes belong to the class of proteins; but each of them is a distinct chemical species, each is a macromolecule created by the assembling, in a precisely determined sequence, of from one hundred fifty to fifteen hundred chemical radicals belonging to twenty different types.

Responsible for all the chemical activity in the cell, the proteins are also, through their non-covalent but specific interactions, the molecular bases of cellular morphogenesis. In multicellular organisms, morphogenesis is assured by interactions between cells or tissues; M. Wolff has reported admirable examples of these. Though we are still far from being able to produce a molecular interpretation of these phenomena, there is no doubt that here, too, the specific nature of each interaction is due to proteins.

The carrying-out of a cellular "project", then, implies the implementation, simultaneously or one after the other, of the following major operations:

1) The translation into protein structure of the information represented by the structure of DNA. This operation includes the synthesis of several kinds of RNA, each playing an intermediary's role in this transfer of information. A number of specific proteins intervene at each stage along the way.

2) The organization, the structuration of the cellular organelles, assured by elective interactions among proteins.

3) The catalytic activation of some two thousand reactions organized in parallel, divergent, convergent, and cyclic sequences; these assuring both the mobilization of the chemical potential and the biosynthesis of the basic chemical components.

4) The synthesis of two half-molecules of DNA, each directly copied from a pre-existent half-molecule of DNA.

5) The separation of the two resulting molecules, which precedes the very complex mechanism of cell division.

All this chemical machinery functions with an efficiency that approaches perfection. Under good conditions, a bacterial cell carries out its project (its "dream", as François Jacob said in this very hall)—to reproduce its DNA, to become two cells—in something like twenty minutes. Errors serious enough to cause the whole project to fail are extremely rare: in a population in process of growth there is almost no mortality. The synthesis of a protein molecule, involving the bonding of a thousand or so amino acids in a sequence which DNA defines precisely, is accomplished in less than a minute without the proportion of error (though errors there are) ordinarily exceeding perhaps one in a thousand. The energy yield is just about maximal, and the overall material yield is nearly one hundred percent.

Needless to say, the power and teleonomic perfection of so complex a system implies a rigorous coordination of all the activities, of all the exchanges of matter and energy going on therein. It is upon the coordination of these activities more than upon these

activities themselves that the very existence of the system as such finally rests.

Now it seems that we are today in a position where we can point to a specifically coordinating function in certain classes of molecules. These molecules are the so-called "allosteric" proteins. Through their structure they have the capacity to associate, electively and reversibly, with two or more different chemical species; these latter species being, when the case does so require, without any structural analogy each to the other, without any affinity, without any mutual chemical reactivity.

Between these bodies which ignore each other chemically, between whom, if left to themselves, no exchange of energy would take place, no influence would be exercised, an elective interaction occurs through the intermediary of the allosteric protein. The analysis of these interactions and their interpretation is a subject of concentrated research at the present time; and it is to this problem that I intend to devote my lectures this year.

For the moment let it suffice to note the essential: namely, that while these reactions do at first seem excessively complex, one may account for them, at least on a preliminary and approximate basis, by a theory with a simple principle. This theory reposes, in particular, upon certain considerations of molecular symmetry. Most proteins (generally called "globular") are, in fact, made up of a finite number of like subunits, each of which is by itself without any symmetry. However, it may be demonstrated that these asymmetrical subunits are in all probability so assembled that the molecule features the elements of symmetry present in one of the regularly repeating groups. One can therefore say that these molecules make up what we may call "closed crystals". Now the symmetry of these molecular structures itself provides grounds for the interpretation of one of the most remarkable properties of allosteric interactions: their non-linear nature. Thanks in effect to this property, allosteric proteins may be considered as genuine amplifiers for chemical signals, in their functioning comparable to the amplifying relays employed in electronic circuits.

I use the word "relay". It is, I believe, the suitable one. For the role of allosteric proteins is to establish communication, a coupling link between metabolic circuits which, chemically independent, acquire their teleonomic value only be dint of close coordination. The essential point is that these allosteric interactions are *gratuitous,* and that in several senses. Firstly inasmuch as, being non-covalent and reversible, they involve only very faint amounts of energy. But above all they are *chemically* gratuitous in that they are neither subject to nor in any manner limited by the structure, the reactivity, or the affinity of the bodies between which the protein sets up its interaction. This interaction depends exclusively upon the protein itself, upon its structure, freely dictated by DNA.

Here one can clearly see how, thanks to the "invention" of allosteric proteins, molecular evolution was able little by little to free living systems from chemical restraints (whether structural or thermodynamic) which otherwise would have prevented the emergence of that prodigious functional edifice, the cell such as we know it today.

It remains, nevertheless, that although our theoretical generalizations are bringing a wide range of possible applications to light, thus far the essential role of the allosteric interactions has been experimentally demonstrated only at the cell level. Multicellular organisms succeeded in emerging thanks only to the development of new networks of coordination. In order of complexity, we should differentiate between:

1) Coordinations which result from direct, contactual interactions between cells.

2) Endocrine correlations.

3) The nervous system.

All these systems function through the intermediary of chemical signals which, in the last analysis, act at the cellular level. How these signals act within the molecule—whether they are mediators of the nerve impulse, like acetylcholine, or hormones such as the steroids—is still almost completely unknown. It is tempting to suppose that these bodies might play the part of allosteric ligands,

which would imply that, without significance in and of themselves, their interpretation as signals would depend exclusively on the cellular program. Thus might one be able to explain how a single body can produce different primary effects, depending on the tissue or the recipient organ.

These for the time being are no more than speculations. It is certain, however, that embryology, endocrine physiology, neurophysiology and molecular biology must now join forces in this domain to seek the solution to these basic teleonomic problems.

Let us say that I would be surprised—and my faith in the unity of the living world deceived—if man's central nervous system, this prodigious organism of teleonomic coordination, did not in fact use the allosteric interactions already discovered through bacteria as a means of molecular communication.

* * * * * *

Suppose our speculation verified. Would we then have the right to say that we know the ultimate physical basis of thought, of consciousness, of knowledge, of poetry, of political and religious ideas, the bedrock source of the noblest aims and the basest ambitions?

Indeed, yes, we should have to say that all those things, all these beings inhabiting us, are in effect contained, inscribed in the geometrical deformations of several million billion tiny molecular crystals. We should have to say so, just as we are obliged to say that the works of Racine are contained in that book over there, and those of Shakespeare in another.

That a system of differentiated intercellular communications should emerge in the biosphere, that this communications system be capable of transferring to other and distant cells signals relevant to the living experiences of one cell among many, this is most certainly a remarkable accident, probably connected with the acquisition of motility among multicellular beings and therefore associated with that other accident by which tissue with a mechanical function was differentiated. Not an inevitable accident; but one for

which the stage was set once the molecular bases for communication and coordination existed within each cell. That, following other accidents, this system became capable not only of establishing a central coordination, but of recording, combining, transforming, and feeding back information—there is a still more prodigious phenomenon of emergence, but not a paradox once an almost instantaneous network of intercellular communications had been established. As we know, the central nervous system of many animals (and not just of animals designated as "superior") is certainly capable of all these performances, especially highly developed among the social species for whom the communication of information between individuals is a condition for the survival of the group.

Yet only the most recent of these accidents was to be responsible for the emergence, within the biosphere, of a new realm, the noosphere, the realm of ideas and knowledge, born the day when the new associations, the new creative combinations realized within an individual could, through being transmitted to others, outlive him.

Man's central nervous system, though greater in volume, is not, in its overall structures, different from that of other primates. And if since Broca we can recognize certain areas of the encephalor acting as language centers, we cannot yet say whether this faculty of speech is linked to the existence of certain special circuits, present in man but missing in the ape, or associated with the general total increase in the system's capacity to record and combine. I would be tempted to propose the hypothesis that language may have appeared with the help of the emergence of new, and not in themselves especially complex, interconnections in a prehuman who, until then, had a nervous system hardly more developed than that of the higher primates of the present day. But once come into existence, language was bound to confer an immensely increased selective value to the capacity for recording and combining. In this hypothesis, language may have preceded, perhaps by some time, the emergence of a central nervous system particular to man and have contributed decisively to the selection of those variants

aptest to utilize all its resources. In other words, language may have created man, rather than man language.

* * * * * *

...the living are ever, and ever more, dominated by the dead.

— Auguste Comte

With that last consideration, which, true or false, is still pertinent to his domain, a biologist, working in a science which is not designated as "humane", ought perhaps to close his lecture, leaving linguists, psychologists and philosophers to pursue the discussion. And yet, though un-material and populated by abstractions, the noosphere presents close analogies with the biosphere whence it emerged. A transmittable idea constitutes an autonomous entity (in the sense one speaks of a mathematical entity) of itself endowed with emergence and teleonomy, capable of preserving itself, of growing, of gaining in complexity. And is therefore the object of a selective process of which modern culture is the current but in every way evolving product. Perhaps from a very great mind we shall someday have, as a pendant to Darwin's work, "A Natural History of the Selection of Ideas." We can tell that the laws governing this selection are necessarily very complex, since it works on two levels, as it does with a parasite species. The success of an idea will depend, first of all, on its power to break through, to invade, this no doubt proceeding in some way from its own structure, its capacity to dominate or assimilate other ideas, but without any immediate hinge upon the selective value of this idea for the man or the group accepting it. A parasite invested with such virulence and transmissibility that it unfailingly destroyed all representatives of its chosen host would disappear of its own. Such has been, and yet will be, the fate of many ideas.

Just, also, as certain extreme differentiations, at first sources of success, have seen whole groups go to their annihilation given a

modifying of the ecological context (groups, for example, like the great reptiles of the Secondary Era), so may we observe today that the extreme and proud dogmatic rigidity of certain religions (such as Islamism, Catholicism, or Marxism), source of their earlier conquests in a noosphere which is no longer ours, has now become a critical weakness which will lead them, if not to disappearance, certainly to agonizing revisions.

Common sense is the most widespread thing in the world. And yet, till now, I alone have understood its use.

—Paraphrase of the "Discourse"

One would indeed like to know the future and fate of the most powerful idea ever to have emerged in the noosphere: the idea of objective knowledge, defined as having no other source but the systematic confrontation of logic and experience.

The history of this idea is itself obscure. It must surely be as old as man himself, for no individual, no society could have survived which did not put it in practice. It is doubtless because of its so very deep root in praxis that the emergence of this notion has been so difficult and slow. This may be the explanation for why whole civilizations, and some of the highest, like the Chinese, never managed to evolve this idea, while in Western Europe it took over two thousand years, from the Pre-Socratics to Galileo and Descartes, to prepare the advent of modern Science.

Thus we are dealing with an idea which through its very simplicity, through its apparent aridity, is almost devoid of invading potential, hence completely without arms before those ideas, rich in ethical content, which claim to offer a solution to the problem of the human condition. If in the end, against all the odds, this idea has won its way through, that is exclusively because of its selective value at the second level, the level of praxis; because, that is, of the vast power it placed at men's disposal.

It imposed itself, it created the modern world; it was not adopted by and for itself, nor is it yet, and the Pascalian abyss its light reveals and the anguish that abyss inspires are ever there, more present than ever before. The old myth of the tree of knowledge bears witness that the terrors of knowledge are ancient terrors; but it is a modern poet who says:

Brothers, touch not gluttonous Science
That off the forbidden vines seeks to steal
The bloody fruit we must not know.

Modern man's estrangement before scientific culture, maker though it is of the world he lives in, shows in many other forms besides the naive loathing Verlaine expressed. I take this dualism to be one of the deepest ailments modern societies suffer from, it is the cause of imbalances so grave that they are as of now jeopardizing the realization of the great dream of the 19th century: the future emergence of a society built no longer at man's expense, but for man.

Whence does this estrangement stem? It has several sources, each distinct, but all convergent.

It derives, first and quite simply, from all that which in science defies immediate understanding and intuitive grasp. Relativity, quantum theory or the mechanism of molecular emergence—I am speaking of more than these. The techniques contemporary science has engendered are beyond the understanding of most men and for them represent a cause of permanent humiliation. Unless, in order to compensate for their sting, these perplexities, amalgamated with certain age-old myths, end by being blended into a sort of neo-esotericism whose power of conquest seems to be considerable.

In the second place, there are the abuses of power for which science is held finally responsible. From these beliefs a whole literature has sprung, and the archetype of the paranoid scientist, who will go to criminal lengths to carry out his insane experiment,

was born long before Hiroshima. From Frankenstein, by way of Dr. Moriarty to Dr. Strangelove, the line is direct.

Each of Science's conquests is a victory of the absurd.

—McGregor

Much deeper, more widespread and more worrying, is the feeling to which Kant himself admitted: that science makes man a stranger in a cosmos in which he no longer has an appointed and necessary place. That man has no importance in the universe, that he carries no weight there, and that if he did emerge, it was by pure chance: this capital result of scientific inquiry is also the most unacceptable. Refusal, recourse to transcendence or to some universal entelechy or other does not demand such a degree of objective asceticism, and facilitates assigning a supposedly nobler and more significant origin to our human condition.

The probabilist ideas of modern science are plainly even more offensive than were the mechanistic theories of the early 19th century. Laplace's world was less frightening than ours. In it man had his inevitable place, prepared for him since the beginning of time. It might not be much of a niche; it was something all the same. But that man be the sum product of an incalculable number of preciously preserved random events, how believe this, how face it otherwise than by testing it against biological man, at least against his works? How could pure chance ever have written the *Odyssey, Andromaque,* or the *St. Matthew Passion?*

The universe has only sounds. Man chooses among them and makes a music in his own image which wonders him.

—McGregor

It is possible to calculate the chances of obtaining the works of Shakespeare from an ape at a typewriter. The likelihood is as great

as that of seeing water freeze in a saucepan over a fire—the which, as Borel says, could properly be called a miracle. However, if, as written by Shakespeare, those works owe their emergence to a sum of fortuitious events, then the initial likelihood of their getting written was no greater than with the ape as author. It is therefore a miracle.

This logic is beyond attack. It has only one defect: it is applicable to any single event that has occurred in the universe, since, *a priori,* the probability of such an event is infinitesimal. But the universe exists; events there must be, and all equally improbable. And man happens to be one of them. He won the jackpot. Should he despair or reject the science which forces such ideas upon us? Despair of a man convicted in his own eyes of absurdity and refusing the sentence: a theme which has nourished many of our greatest contemporary works.

> *Knowledge of outward things consoles me not for my inward feelings, in time of affliction: but what is mine from the study of moral science will ever console me for my ignorance of those external sciences.*
>
> —Pascal

Having discarded these confusions, this fear of the unknown threatening to disclose itself, this wounded pride, the ultimate argument remains: that objective knowledge is ignorant of values; that while it has succeeded in destroying the traditional foundations of the various religious ethics, it cannot, by its very nature, provide any other. And that, the function of philosophy being before all else to establish a system of values, philosophy must seek the bases for it outside science, if not on this side of science, then beyond.

Pray forgive me for having the temerity to venture into such a subject. But how is a man of science and particularly a biologist to hide his anxious concern before this inevitable paradox: if he is a man of science, he has *chosen* to become one. Through this choice

he was signaling his adherence to a certain set of values; intentionally or implicitly, he was taking on an ethic. He chose a discipline and accepted to submit himself to it: a discipline with, indeed, all the word implies of moral rigor, without which logical rigor and objectivity would be inaccessible.

Science is ignorant of values; the conception of the universe science today enjoins upon us is devoid of any ethos. Yet research is in itself a form of asceticism; it necessarily implies a system of values, an "ethic of knowledge"—whereof, however, it cannot objectively demonstrate the validity.

We are faced, then, with the following contradiction: modern societies dwell within, affirm, still teach—without for that matter believing in them—value-systems whose bases are in ruins; and at the same time these societies, whose fabric is being woven by science, owe their emergence to the adoption (most often implicit and by a very few men) of this ethic of knowledge they know nothing of. There is the very root of contemporary alienation.

What then is this ethos, this creator of knowledge? I believe it to be still poorly understood, even by men of science themselves. Not so by Nietzsche, however, who bared, violently, its fearsome secret:

> *...All sciences today work for the destruction of man's ancient self-respect... They offer their austere and brutal ideal of stoical ataxy as a means to help men entertain the self-scorn which they have obtained with such great effort, and do so by offering that self-despising as man's ultimate, most serious title to self-respect....*
>
> —Nietzsche

I pointed out a short while ago that the idea of objective knowledge, at first enclosed in the practice of the mechanical arts, had taken centuries to emerge as a concept in the noosphere. Still today we often confuse the ethics of knowledge with scientific method itself. But method is a normative epistemology, not an

ethic. Scientific method tells us how to seek. But who tells us that we have to seek, and that to do so we must adopt the method, with the asceticism it implies?

And here arises yet another misunderstanding. Today, on all sides, voices come out in defense of pure research, free of any immediate contingency, but champion it, precisely, in the name of praxis, in the name of potentials and powers as yet unknown which research alone can reveal and harness. I accuse men of science of having often, too often, entertained this confusion; of having lied about their true purpose, talking of power but with the motive, actually, of feeding the knowledge which alone matters to them. The ethic of knowledge is radically different from religious or utilitarian systems which in knowledge see not the goal to be reached, but a means to attain it.

In the ethic of knowledge the single goal, the supreme value, the "sovereign good" is not, let us admit it, the happiness of mankind, still less mankind's temporal power or comfort, nor even the γνωθι σεαυτον , the Socratic "know thyself," it is objective knowledge itself. I feel that this has to be said; that this ethic has to be systematized, its social, moral and political consequences distinguished; that we have to broadcast it and teach it; for, creator of the modern world, it alone is compatible with that world. There must be no hiding that this is a severe and constraining ethic which, though respecting man as the sustainer of knowledge, defines a value superior to man. It is a conquering ethic and in some ways Nietzschean, since its core is a will to power: but power only in the noosphere. An ethic which will therefore teach scorn for violence and temporal domination. An ethic of personal and political liberty; for to contest, to criticize, to question constantly are not only rights therein, but a duty. A social ethic, for objective knowledge cannot be established as such elsewhere than within a community which recognizes its norms.

To the men of today what ideal is there to propose, what ideal above and beyond themselves, if not the reconquest, through knowledge, of the nullity of which they themselves have been the first discoverers?

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